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AUTHOR Rudnitsky, Alan N.; Garlock, Victor P.
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ABSTRACT

Recent research indicates that content structure is, to some extent, mapped into cognitive structure. This study examines whether or not mapping of content structure into cognitive structure is related to students' ability to recall the content. Findings indicate that the cognitive structure of students with high recall ability does not resemble content structure, while that of students with moderate recall ability does approximate content structure. "More-able" students seem to process and store information in a manner which is qualitatively different from that of "less-able" students. These high ability students may restructure content to fit existing cognitive structure, while less able students learn by rote. (Author)

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THE DIFFERENTIAL STRUCTURING OF CONTENT IN MEMORY

Alan N. Rudnitsky
Smith College
Victor P. Garlock
Cornell University

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A significant amount of research has been done during the last decade which examines methods for representing the structure of prose material, the structure of memory or cognitive structure, and then examining relationships between prose structure and cognitive structure. This research has varied both in terms of what has been examined (i.e., various lengths of prose or instructional content and various subject areas or disciplines) and how structure has been assessed (i.e., word association, graph building, card sorting, analysis of recalled prose and transfer tasks to get at cognitive structure and semantic, syntactic, and sometimes logical analyses to get at prose structure). The theoretical and philosophic assumptions underlying this research also vary. Researchers in the field have held information processing viewpoints, associationist viewpoints, and cognitivist viewpoints, to name a few. A key common element of these viewpoints expressing the relationship of content and cognitive structure is well stated by Ausubel.

> In our opinion, the most significant advances that have occurred in recent years in the teaching of such subjects as mathematics, physics, chemistry, and biology have been predicated on the assumption that efficient learning and functional retention of ideas and information are largely dependent upon the adequacy of cognitive structure. And since existing cognitive structure reflects the outcome of all previous assimilation processes, it, in turn, can be influenced, substantively, by the inclusiveness and integrative properties of the particular unifying and explanatory principles used in a given discipline, and, programmatically, by methods of presenting, arranging, and ordering learning materials and practice trials.[1]

This paper represents a further analysis of data generated in a study which built on the work of Richard Shavelson and his colleagues.

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[1]Ausubel, D.P. Educational Psychology: A Cognitive View, New York: Holt, Rinehart and Winston, 1968, p. 128

Their work addresses some of the major methodological criticisms of research on prose learning, namely the pitfalls of investigating only short pieces of discourse. This criticism is expressed by Chafe (1972) as he points out that prose learning research has focused on "the structure of sentences in isolation with only peripheral attention to larger stretches of speech." Crothers (1972) asserts that the "proper unit of analysis" is "overall knowledge structure and not a set of independent sentences." Rothkopf (1972) seems to be agreeing when he contends that"... certain formal characteristics of language that have been shown by experiment to affect verbal learning may not be very powerful in determining what is learned from substantial quantities of written discourse."

Shavelson and his colleagues have conducted a number of studies concerned with the assessment and representation of content and cognitive structure (Shavelson, 1971, 1974; Geeslin, 1973; Shavelson and Stanton, 1975; Geeslin and Shavelson, 1975; Stasz, Shavelson, Cox, Moore, 1976). This research has been focused on the structure of instructional unit-sized pieces of discourse rather than on the structure of paragraph sized passages. Shavelson (1971) defines content structure as the key concepts in a subject matter and their relationship. Content structure is assessed by grammatically analyzing sentences in discourse which contain two or more key concepts. These parsed sentences are converted into directed graphs using rules developed by Shavelson. Digraph theory (Harary, Norman and Cartwright, 1965) is applied to transform these graphs into a distance matrix indicative of the (semantic) distance between key concepts in prose. This matrix can then be graphically represented through a multidimensional scaling or hierarchical clustering procedure.

Shavelson has used word association, graph construction, and card sorting tests as measures of subjects' cognitive structure.

In a methodological investigation, Rudnitsky (1976) employed these techniques to represent content and cognitive structure. This study began by identifying the key concepts presented in a two-year college botany unit entitled "Growth and Development" (of vascular plants). Seventeen concepts were identified and then two instructional presentations were developed, each of which organized the key concepts differently. One organization (termed World-related) structured the concepts on the basis of spatial and temporal characteristics of plants. This version first discussed the seed, then the root, and lastly the stem of vascular plants; these being spatial characteristics of plants. Temporally a plant develops from a seed, the root is the first emergent plant part followed by the stem. Structure, tissues, function, and growth are discussed for each plant part. The second version (termed Concept-related) organizes the unit around the "higher order" concepts (identified by subject matter specialists). This version deals with plant structures, tissues, growth, and functions. The appropriate aspect of plant parts (i.e., seeds, roots, and stems) are discussed together for each major concept.

While the information contained in both versions is identical, it was hypothesized that a group instructed in one version would structure the concepts in memory differently than a group instructed in the second version. In terms of methodological questions, the study investigated the discriminatory power of Shavelson's technique for analyzing content structure and for assessing cognitive structure. The grammatical analysis employed by Shavelson uses sentences as

a unit of analysis. Since the sentences of the two versions were essentially alike, this analysis did not discriminate between the two versions of the botany unit.

Another technique was developed to analyze the two units. This technique was termed Judges' Graph Analysis. Five judges (graduate students) analyzed the World-related unit and five judges analyzed the Concept-related unit. Each judge was given a list of the seventeen key concepts and a set of rules for summarizing a unit (see Appendix A). The judges were also given a set of rules for converting a summary into a graphic representation of key concepts (see Appendix A). The information from the graphs of the judges was put into the form of a 17x17 (key concepts) distance matrix. A mean matrix was computed for each unit and used in the study. It was thought that a careful summary and analysis of the script would identify relationships among the concepts that an analysis limited to discrete sentences would not pick up. The multidimensional representations of the judges analysis did suggest different content structures.[2]

The Rudnitsky study employed word association, graph building, and card sorting tests to assess cognitive structure. The word association and graph building tests resulted in similar multidimensional representations while card sorting did not result in comparable representations. A recall-type quiz was administered to the subjects in both the World and Concept-related groups. Four equivalent forms were randomly administered to all students. There

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[2]The judges analysis discriminated between the two versions better than the grammatical analysis did. The representation of content structure reflected, to a reasonable extent, the differences in units. The variation in judged interpoint distances across judges was small. For further information the reader is directed to the Rudnitsky (1976) study.

was no statistically significant difference in recall of content for the two groups. Comparisons of cognitive structure of the two groups was undertaken by comparing multidimensional representations and computing and comparing euclidean distances for the groups.

Consideration of the findings, particularly in terms of an information processing approach (Mayer, 1975) to content structure and its relationship to cognitive structure has led to this reanalysis of the Rudnitsky data. Mayer (1975) suggests a three stage model to describe a student's processing of verbal information. This model considers how much information is received, how much prerequisite knowledge the learner has, and what aspects of the learner's existing knowledge are activated during learning and integrated with the new material. This model is related to Ausubel's (1968) distinction between rote and meaningful learning. Viewing verbal learning in this way suggests that there are students, having particular prior knowledge and a particular learning set who would process information in a way qualitatively different from students possessing a different background or set. Stated another way, content structure might interact with certain cognitive attributes of learners.

This reanalysis examines the possibility that there are identifiable groups of learners affected in predictable ways by content structure. Specifically, learners with adequate prior knowledge and a meaningful learning set may restructure the content as it is presented to "better fit" their cognitive structure. Other groups of learners may learn rotely and attempt to incorporate content structure directly into cognitive structure. Examining the cognitive structure of sub-groups in the Rudnitsky study and comparing them

to the content structure of the appropriate instructional unit would seem to be a step toward answering these questions.

In this reanalysis subjects are divided into subgroups on the basis of their performance on a recall-type test. That is, subjects with high recall scores in each treatment are compared to each other and to subjects with low recall scores. Because this study is a reanalysis rather than a design to test specific hypotheses it suffers certain limitations (e.g., claims can not be made that recall ability affects cognitive structure rather than the reverse), it will focus on the following questions:

1 - To what extent is there an interaction between recall score and content structure in terms of resulting cognitive structure?

1a- Does one particular content structure have a greater impact on cognitive structure than the other?

1b- Are high and low recall groups more related to each other or are they more related to the content structure of their particular treatment?

METHOD

Content and Cognitive Structure

The content structure of the two instructional units is that arrived at through Judges Graph Analysis.

Cognitive structure is measured using a graph construction test (see Appendix A). This was selected over a word association technique because subjects manipulate and attempt to represent the concepts in a manner similar to the procedure followed in the Judges Graph Analysis of content structure.

For purposes of visualization, content and cognitive structure are graphically depicted using Waern's (1972) approach for representing the structure of similarity (or dissimilarity) matrices.

(Figures 1 through 6). This approach has been found to be preferable to either multidimensional scaling or hierarchical clustering in situations for which no firm ground exists to suspect underlying structure as being rooted-hierarchical or spatial (Preece, 1976).[3] It should be noted that these representations are only suggestive and aids in visualizing structure.

Subjects

The subjects were 116 students enrolled in a botany course at Corning Community College. They were both first and second year students. All students were non-science majors taking this botany course to fulfill their science requirement for the Associates degree.

Procedure

At the beginning of the school year, students in the botany course are randomly assigned to sections. The course is audio-tutorial, and students work through the material at their own pace, using the laboratory at times they choose. Sections meet for hourly exams and other course business once weekly. To assure a balance of testing times, one section (3rd Wednesday section) was randomly selected and other sections were assigned to either the World or Concept related version of the instructional unit. (Concept sections: Monday - 1,3,5,7; Tuesday - 2,4; Wednesday - 2,4,6; Thursday - 1,3,5)(World sections: Monday - 2,4,6;

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[3]Note that Waern's approach leaves configural orientation very much at the discretion of the researcher. In an attempt at achieving a more "inflexible" solution, results from multidimensional scaling solutions (Appendix B) were used to make decisions regarding orientation. (see Rudnitsky, 1977).

Tuesday - 1,3,5; Wednesday - 1,3,5; Thursday - 2,4). As a further check on group equivalence, high school average and average in botany to date were compared and found not to differ significantly (High school average: 78.49, 78.93; Botany average: 79.47, 81.01).

Subjects come into the lab to work through the unit. They were given (according to hourly sections) either World or Concept-related materials. Upon completion of the unit, subjects were given one of four forms of a recall-type quiz (intraclass reliability: form A-.74, form B-.72, form C-.76, form D-.74). Thirty-five subjects using the World-unit and 23 using the Concept-unit were randomly selected to respond to a graph construction test as a measure of cognitive structure (see Appendix A).

Sub-groups were formed on the basis of recall test scores. A criterion of z-score - +.50 was used to form the high recall sub-groups for World and Concept related treatments and a z-score of -.50 was used to form low recall sub-groups. (see Table 1)

Table 1

Composition of Sub-Groups

treatment	sub-group	number of subjects
World-related	high recall	10
	low recall	13
Concept-related	high recall	9
	low recall	7

Analysis

Content structure and cognitive structure for the various sub-groups are compared by using Johnson's (1967) procedure of computing rank order correlations between the distance matrices. This procedure is found by Preece (1976) to be the most preferable technique for such comparisons. This involves rank ordering the 136 cells of the 17 x 17 half matrix and computing a Spearman rank-order correlation corrected for ties (Siegel, 1956).

Results

Representations of content and cognitive structure using Waern's (1972) graphic approach are presented in Figures 1 through 6. The seventeen key concepts are abbreviated. These abbreviations are explained in Table 2.

Table 2

Abbreviations of Key Concepts

SD - seed	M/D - monocot/dicot
RT - root	GM - germinate
SM - stem	MER - meristematic region
GW - growth	ELN - elongation region
STR - structure	MAT - maturation region
TS - tissue	CLD - cell division
FN - function	CLE - cell elongation
SPC - specialization	CLM - cell maturation
CL - cell	

Spearman rank order correlations between the content and cognitive structure representations are presented in Table 3.

Table 3

Spearman Rank Order Correlations

	content str. concept unit	content str. world unit	cognitive str. low recall-concept	cognitive str. low recall-world	cognitive str. high recall-concept	cognitive str. high recall-world
concept unit	--	.52*	.39*	.28*	.57*	.60*
world unit		--	.16	.16	.36*	.46*
low recall-concept			--	-.05	.43*	.24*
low recall-world				--	.14	.25*
high recall-concept					--	.51*
high recall-world						--

*$p < .01$, (Kendall, 1948)

Figure 1. Graphic representation of World-related unit's content structure, (cut-offs- 1, 2).

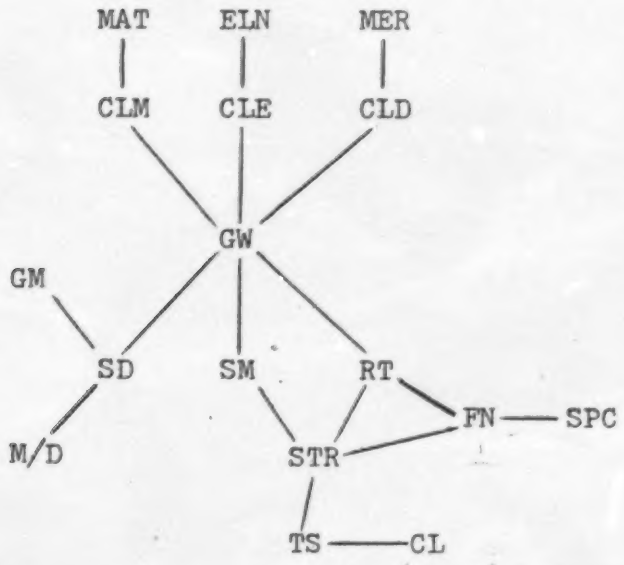


Figure 2. Graphic representation of Concept-related unit's content structure, (cut offs- 1, 2).

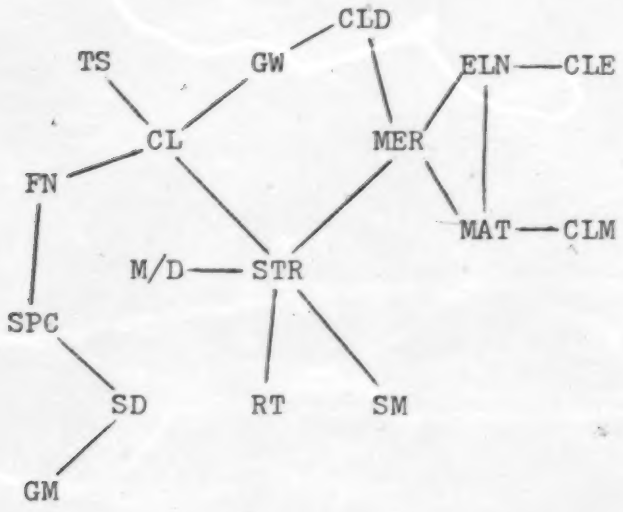


Figure 3. Graphic representation of high recall/World-related sub-group's cognitive structure, (cut-offs- 1.9, 2.4, 2.9).

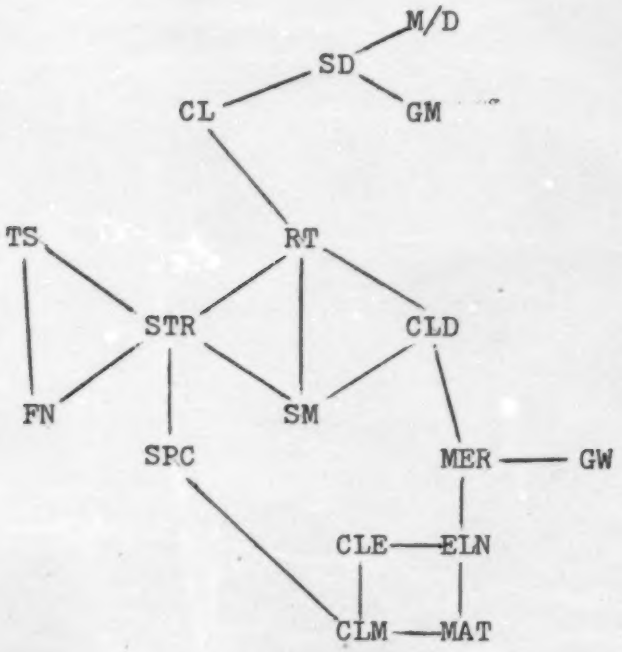


Figure 4. Graphic representation of high recall/Concept-related sub-group's cognitive structure, (cut-offs- 1.9, 2.6).

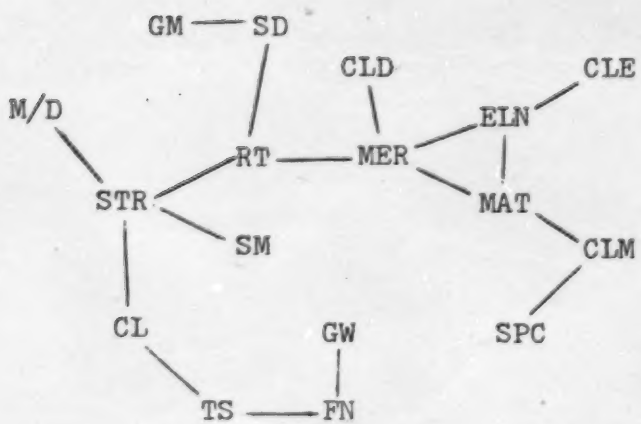


Figure 5. Graphic representation of low recall/World-related sub-group's cognitive structure, (cut-offs- 2.7, 3.0)

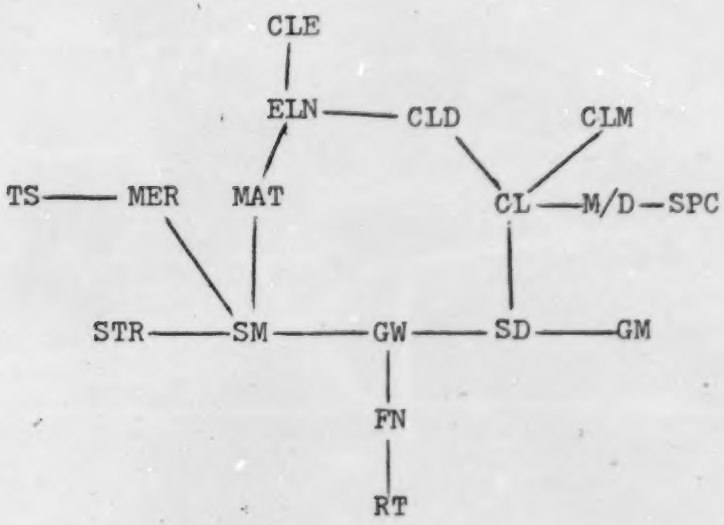
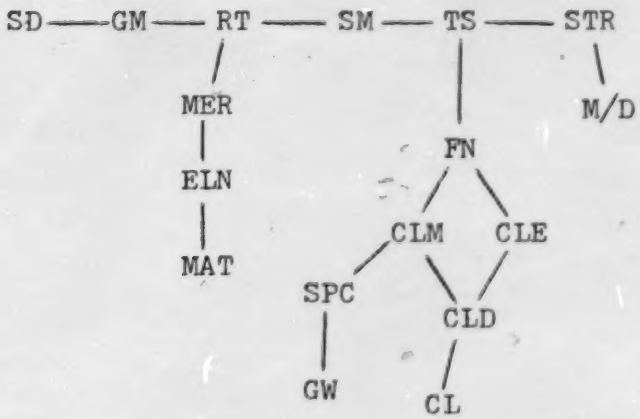


Figure 6. Graphic representation of low recall/Concept-related sub-group's cognitive structure, (cut-offs- 2.0, 2.7).



In addition to interpreting results cautiously because this study is a reanalysis, a fair interpretation must begin by pointing out the .52 correlation between World and Concept units. These units were not constructed so as to be as different as possible. In fact, only 7 out of 17 concepts were organized in a substantially different manner in the two versions. This would lead one to expect the two versions to be related. In terms of interpretation, one does not know on the basis of correlations, which matrix cells (i.e., concept distances) have been changed. For these reasons, when correlations indicate an interesting relationship or pattern (or lack of one) the graphing solutions are then discussed.

The strongest relationships evident in the results are: 1) the relationship between the two high recall groups and 2) the relationship between both of these groups and the content structure of the Concept-related unit. The graphs further support this relationship in that for the content structure of the Concept-related unit (Figure 2) and for the cognitive structure of the high recall group (Figures 3 and 4) STR (i.e., structure) occupies a "central" position and growth regions (i.e., MER, ELN, MAT) and growth processes (i.e., CLD, CLE, CLM) are similarly organized.

The World-related unit is also related to the cognitive structure of the high recall groups (r_S=.36 and..46). Although growth is the central concept (Figure 1), growth regions and processes do evidence a regular pattern and structure, while not a "central" concept is a concept with several interrelationships.

The low-recall, concept group has a stronger relation to both high recall groups and to the concept unit's structure than is true for the low recall, world group. The two low recall groups' cognitive structure are essentially, unrelated.

Conclusions

The cognitive structure of the high recall groups resemble content structure to a greater extent than do the cognitive structures of the low recall groups. It is interesting that both Concept and World-related, high recall groups resemble the Concept-related unit more than the World-related unit. This may indicate that "more able" students restructure content to fit their own cognitive structure; the moderately strong relationship between both high recall groups may be further evidence for this. A tentative postulation is that these high recall students already have a conceptual orientation and hence their cognitive structure is more like the structure of a conceptually oriented unit. That they do, in fact, restructure content seems supported by the World-related groups' relationship to the Concept unit's structure.

Other relationships of interest are those between the low recall, concept group and the concept unit (r_s=.39) and between this group and the high recall, concept group (r_s=.43). This suggests that the Concept-related unit had a greater effect on cognitive structure than did the World-related unit.

Although the conclusions are tentative, the overall pattern of relationships as well as the insights afforded by the visual representations do support the notion that content structure affects certain groups' cognitive structure differently than that of others. While recall is an effect (rather than a cause) of cognitive organization, it does provide evidence that identifiable groups of students process information differently. It also seems fair to postulate that prior knowledge and learning set may lead one to process verbal material by restructuring it and incorporating it into cognitive structure. A study designed to test this explicitly would seem to be

a worthwhile step toward understanding the processing of verbal information.

The evidence that the Concept-related unit had a more powerful impact on cognitive structure than did the World-related unit suggests other questions for further research. With more instructional time and emphasis placed on structure, could the cognitive structure of a group like the low recall group be affected to a greater extent? What effects might this have on cognitive factors like recall ability, retention and transfer?

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APPENDIX A

Rules for Summarizing a Script

1. Any paragraph or section of script dealing with "key concepts" must be summarized.

   a. Any paragraph or section of script dealing with material other than key concepts should be omitted from the summary (sections directing the student to a diagram, sections dealing with other content).

2. The summary of a paragraph or section of script should be as brief as possible but still include key concepts.

3. Summary sentences should be clear and need not be taken directly from the script.

4. The summary of the script must proceed in the order of the script.

5. Information or prose in the script which relates two or more key concepts together must be summarized.

6. You may view this task as one of constructing an abstract. An attempt should be made to condense paragraphs into sentences.

7. Paragraph structure of the summary is unimportant. The summary can be treated as one paragraph.

8. Do not use pronouns when referring to key concepts.

Procedure for Converting a Script Summary to a Graphic Representation of Key Concepts

1. Read through the script summary.

2. Underline all key concepts in the summary.

3. These key concepts will be the "points" or "nodes" of the graph.

4. Starting with the beginning of the summary and working sequentially through, indicate relationships between key concepts directly related in the script.

   a. Determining whether or not concepts are related in the script is being left largely to your individual judgement. The dimension of importance here is whether or not a relationship between two concepts as presented in the summary is an element of the meaning of the subject matter (in this case growth and development of higher plants).

   b. A relationship must be direct to be indicated by a line on the graph. That is, two concepts cannot be connected with a line if they are related through a third concept in the summary. For example:

      > There are over 100 elements represented in the periodic table. The periodic table is arranged according to atomic weight. Although elements and atomic weight are directly related to periodic table, they are not directly related to each other.

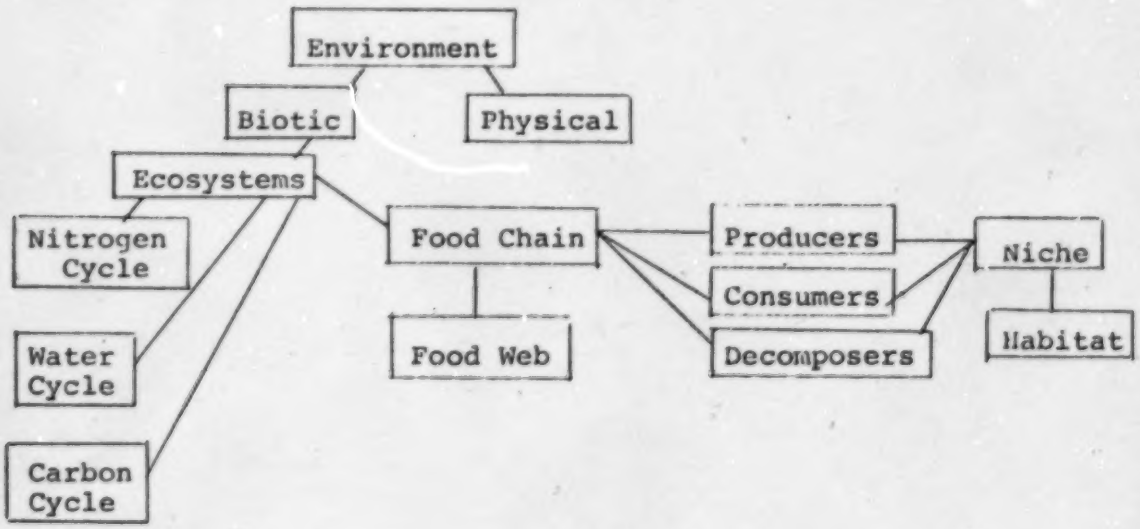
5. Repeat key concepts as infrequently as possible on the graph. That is, try to arrange the graph so that key concepts are used only once. If this is not possible, try to minimize repetition of key concepts.

6. After an initial representation of concepts, "play around" with them for a while to see if there is one best spatial arrangement.

INSTRUCTIONS

This is a test that asks you to arrange concepts on a sheet of paper. You should arrange the concepts in the way that is most meaningful to you. Concepts which you think are closely related will be placed close together on the paper. The concepts may be clustered into tight groups or spread out. You should connect concepts which are related by lines.

For example, the following is a sample arrangement for ecology.



Not all the important concepts are included in this example, and you may disagree with the way they are related. However, it does illustrate the kind of arrangement you should make. Note, for instance, that producer is much more closely related to consumer and niche than it is to carbon cycle.

You will find a sheet of paper and an envelope containing 17 labels attached to this sheet of instructions. Each label has a concept from plant growth and development written on it. Arrange the labels on the paper. When you are satisfied that you have represented the concepts in the most meaningful way, peel off the back of the label and affix it in position.

Are there any questions about what you are supposed to do?

APPENDIX B

Figure 1. Multidimensional Scaling Solution of World-related Script

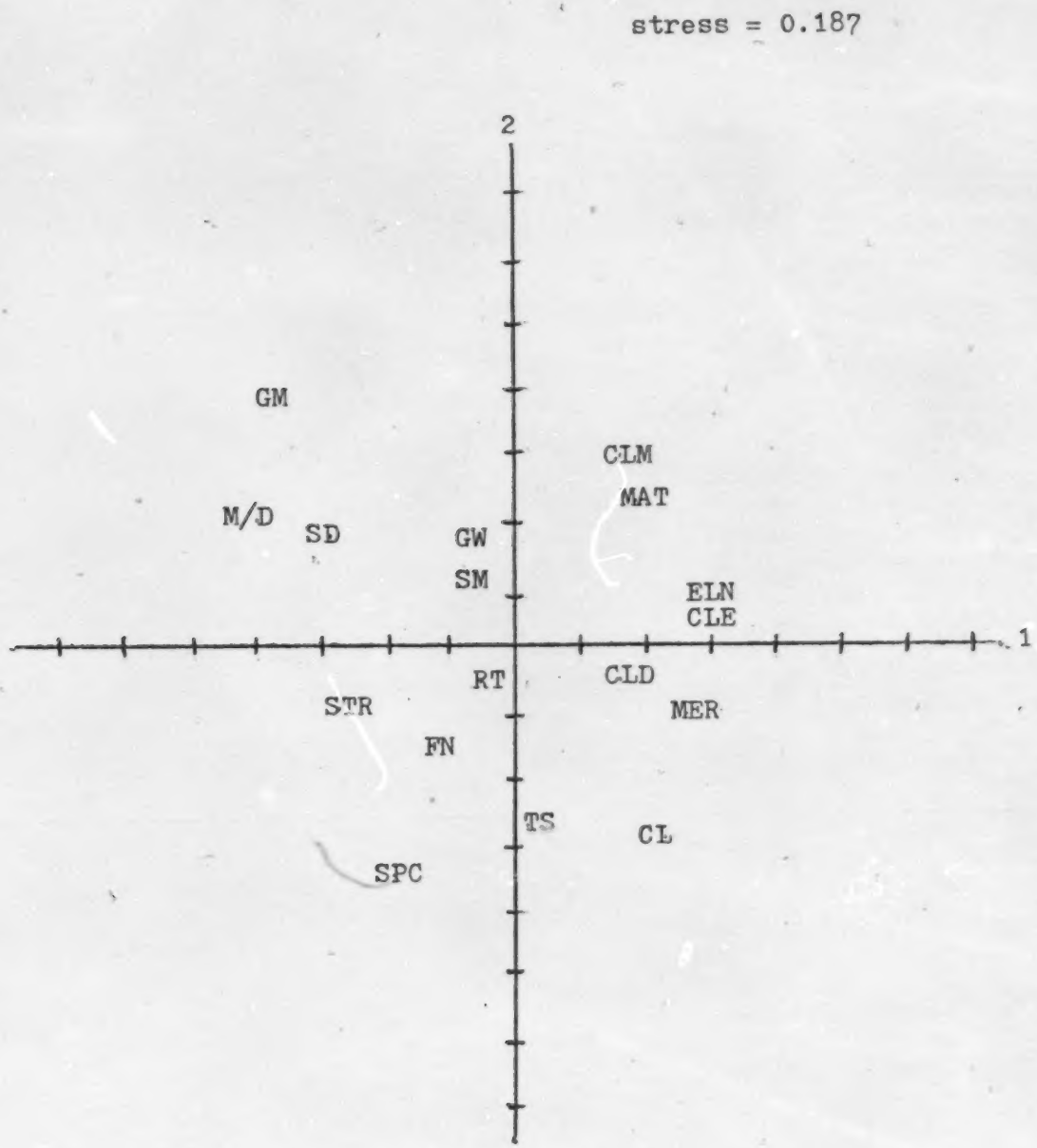


Figure 2. Multidimensional Scaling Solution of Concept-related Script

stress = 0.049

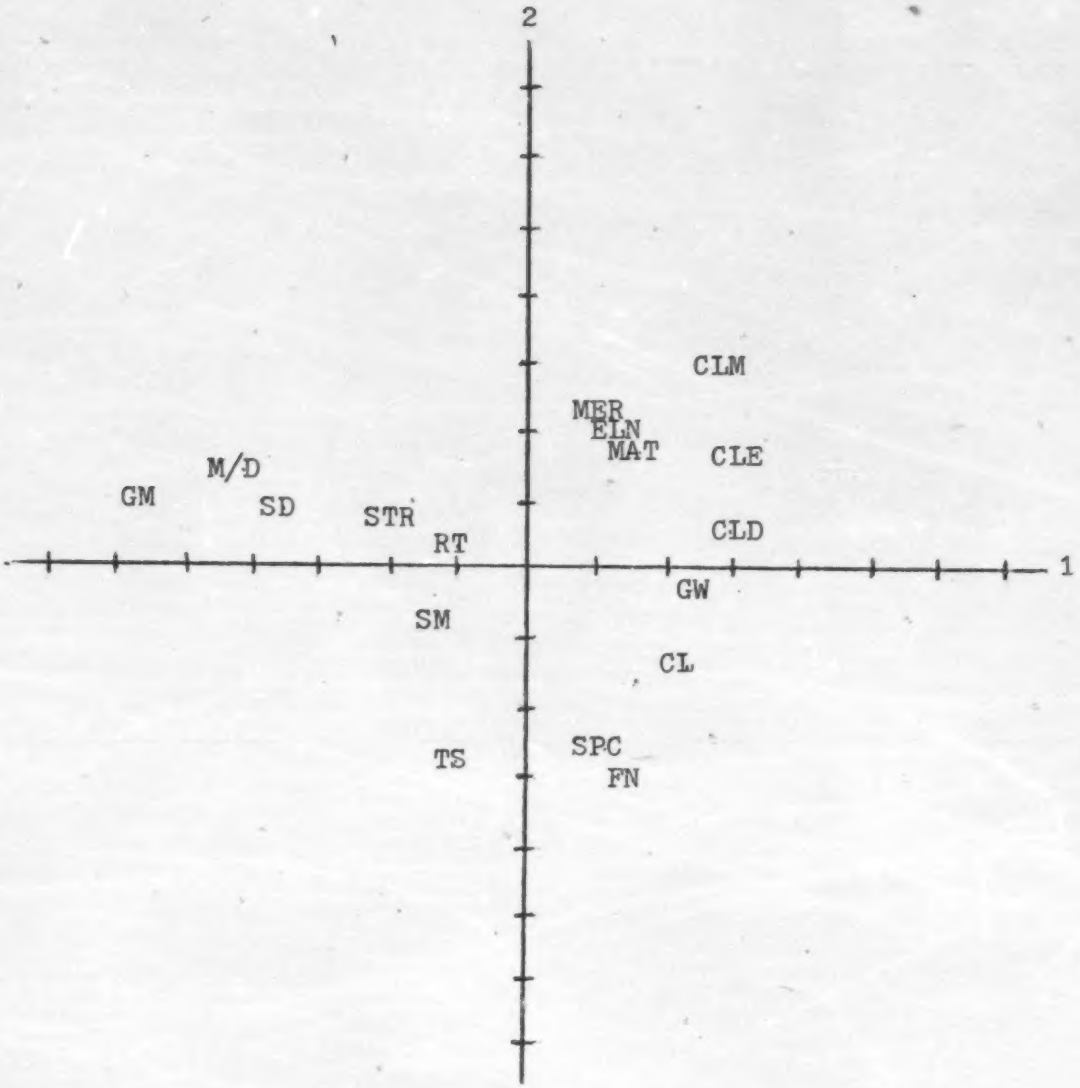


Figure 3. Multidimensional Scaling Solution of Cognitive Structure for High Recall Quiz, World-related Group

stress = 0.484

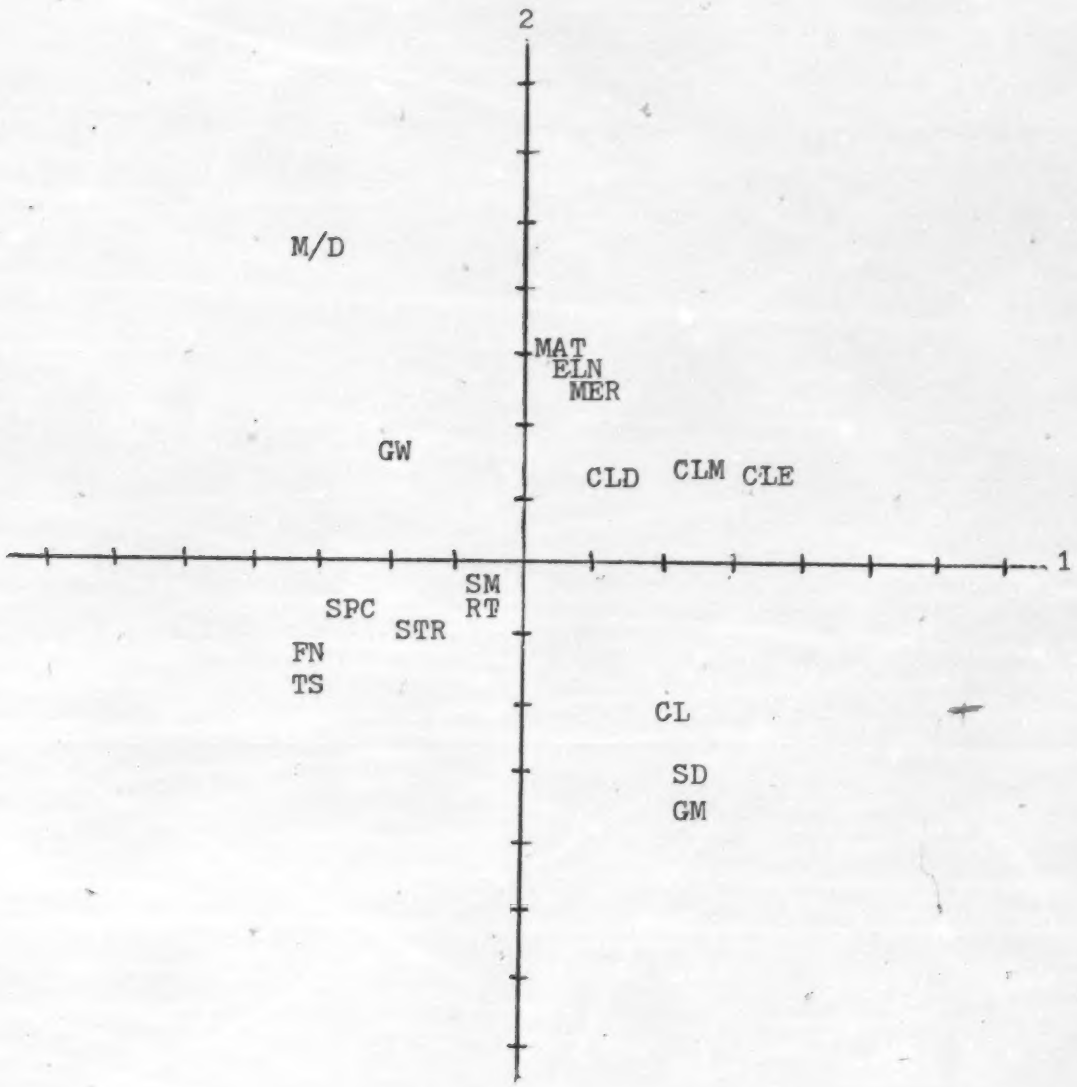


Figure 4. Multidimensional Scaling Solution of Cognitive Structure for High Recall Quiz, Concept-related Group

stress = 0.421

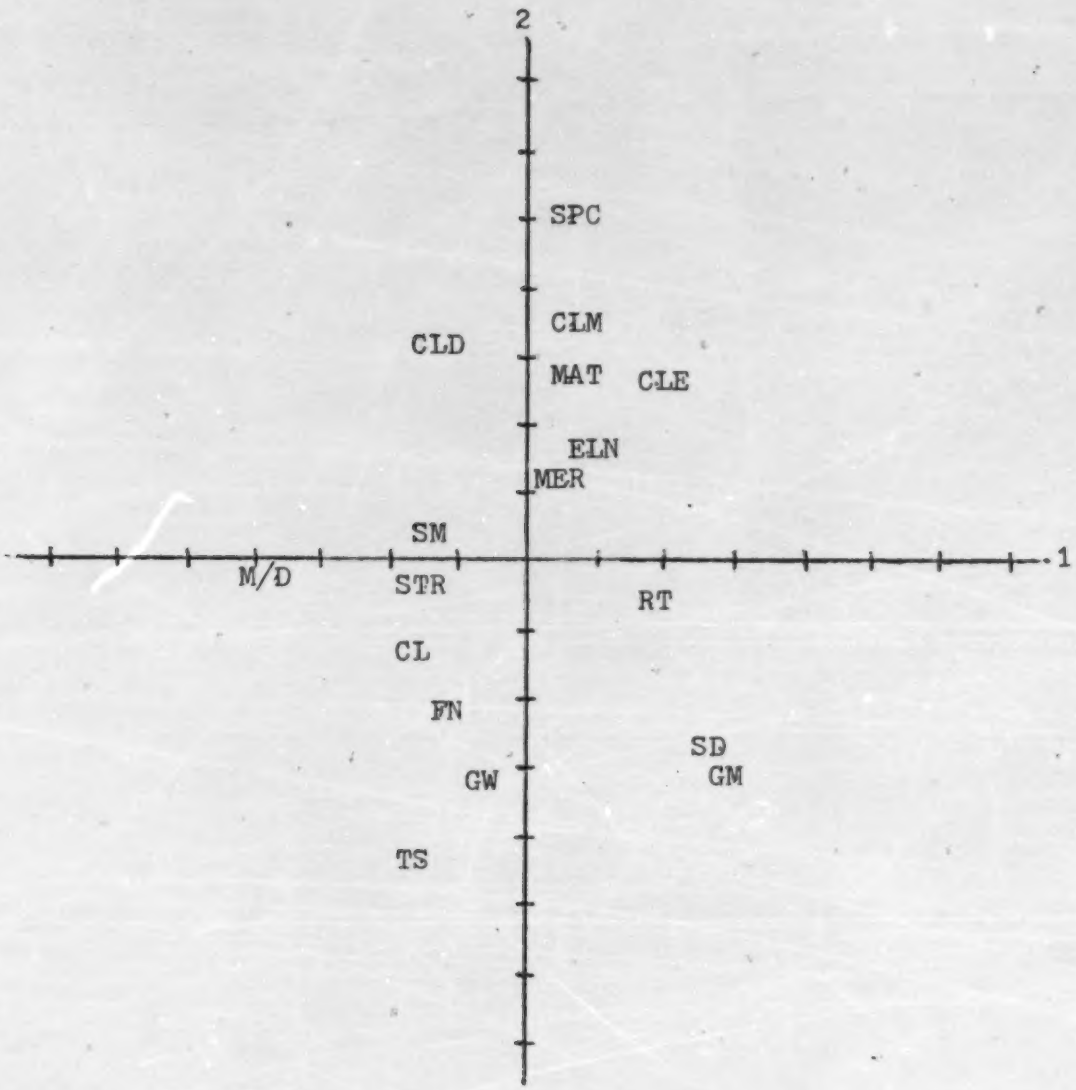


Figure 5. Multidimensional Scaling Solution of Cognitive Structure for Low Recall Quiz, World-related Group

stress = 0.368

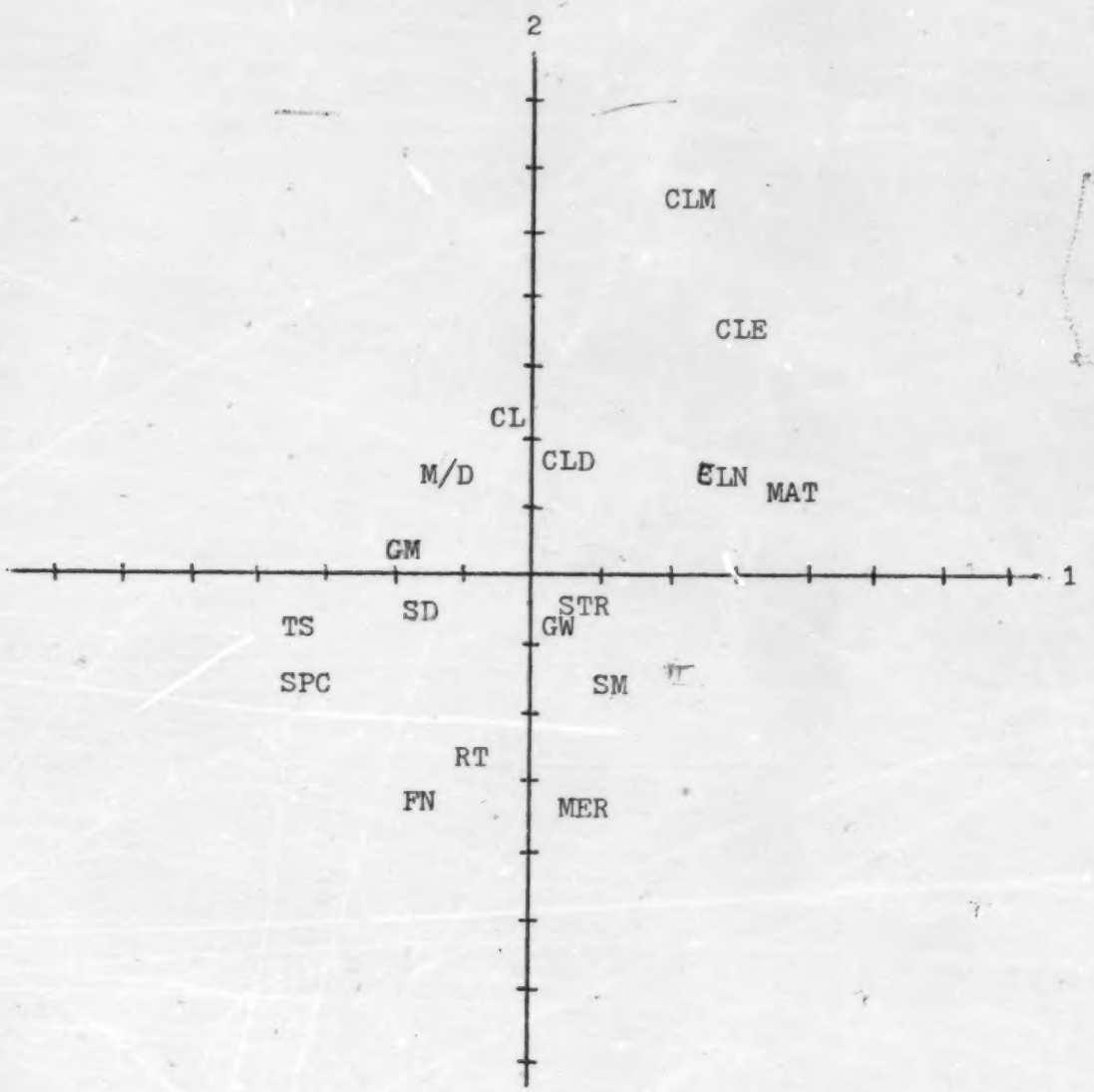


Figure 6. Multidimensional Scaling Solution of Cognitive Structure for Low Recall Quiz, Concept-related Group

stress = 0.289